UM1471
User manual

250 W DC-DC solar module for photovoltaic distributed architecture

Introduction

The STEVAL-ISV013V1 is a fully integrated module designed for a smart junction box in distributed photovoltaic architecture. The module represents an easy-to-use, fully-protected solution to implement precise photovoltaic panel control, diagnostic and protection.

The STEVAL-ISV013V1 is the base element for a new photovoltaic panel configuration able to increase the panel energy produced and to simplify the photovoltaic field design and realization. Furthermore, the maintenance cost is reduced thanks to the possibility of monitoring the individual panel status and to communicate these data to a remote control unit. The demonstration board realizes an isolated converter to be connected at the output of a single PV panel for distributed MPPT. This voltage is stepped up to the voltage, defined by the inverter, needed to realize a sinusoidal output with a magnitude big enough to transfer energy in the grid.

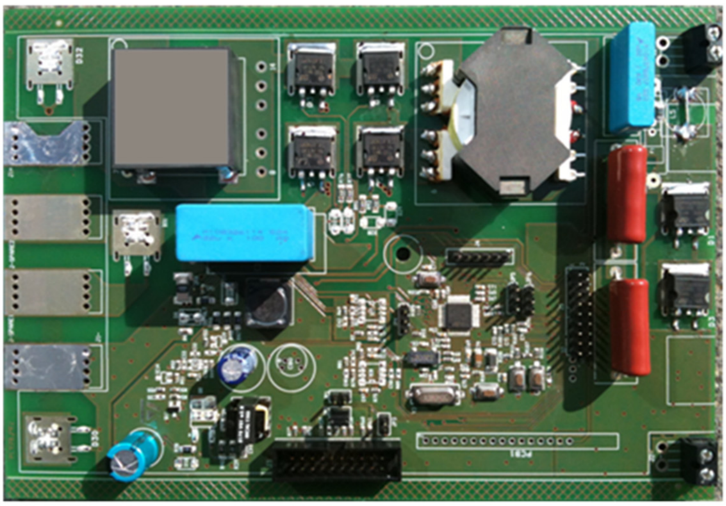
The module features an embedded MPPT (maximum power point tracking) algorithm based on the “Perturb and Observe” (P and O) technique to search for the best operating point of the panel in order to maximize the energy produced in every environmental condition.

The module is internally protected against surge or lightning reaching the connection wires.

The STEVAL-ISV013V1 can integrate a PLM or ZigBee® for communication. The PLM is supported by a proprietary protocol stack for networking. Gateway to RS485 in Modbus is available. The unit is designed to operate in a harsh environment offering a high level of protection and very high reliability.

The ZigBee® module is based on system-on-chip (SoC) technology, integrating both IEEE 802.15.4 radio transceiver and computing capabilities and is designed to run a fully compliant ZigBee® PRO network protocol stack.

Figure 1. STEVAL-ISV013V1 image



AM10609v1

Contents

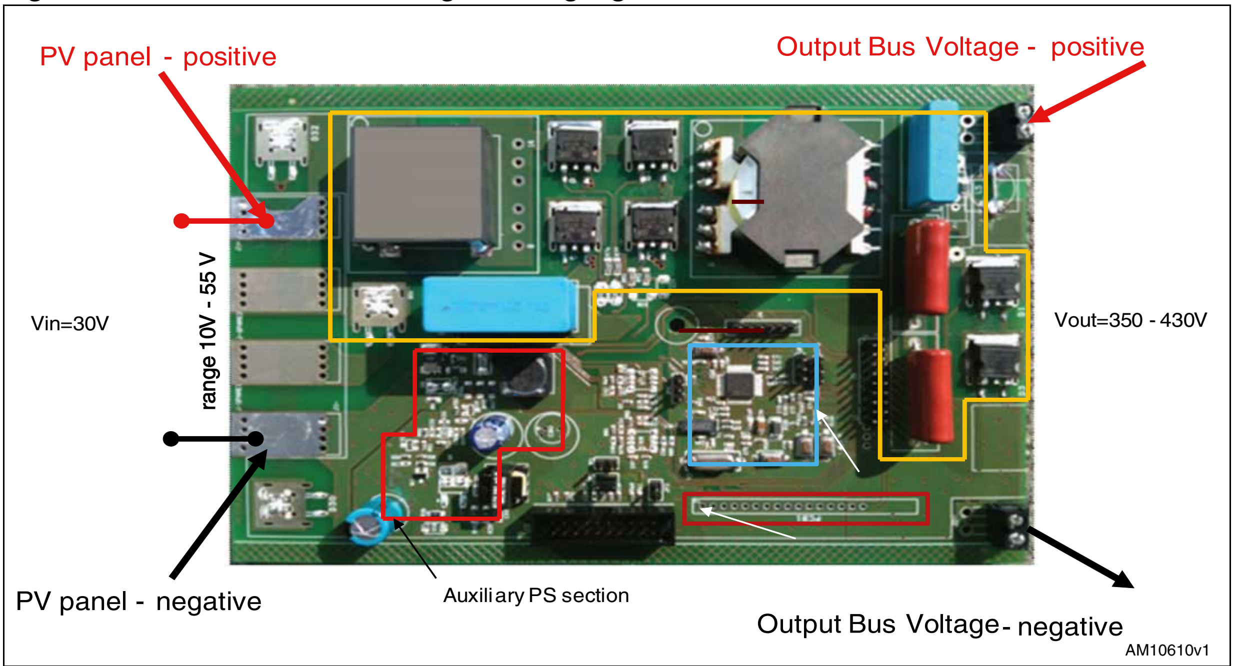
List of figures

1 System description

The STEVAL-ISV013V1 is a smart junction box for photovoltaic panels. It is a high efficiency isolated DC-DC boost converter operating in the input voltage range from 10 V to 45 V and able to step up the panel voltage to the input voltage of a DC-AC converter. In addition, it provides metering and monitoring features and implements some safety functions like fire and anti-theft protections.

A general description of the system is shown in *Figure 2*, with an image highlighting the different hardware sections of the board.

Figure 2. STEVAL-ISV013V1 image with highlighted hardware sections



It consists of several sections as listed below:

- DC-DC converter
- Auxiliary power supply
- Digital control section
- I/O connectors
- PLM - ZigBee external module connector.

DC-DC converter section

The power section, based on an isolated full bridge boost converter, is designed to accept low input voltage in the range 10-45 V. The output voltage is in the range 350-430 V, suitable to directly supply the DC bus of a standard single-phase inverter.

The specifications in *Table 1* for the PV system are used as inputs for the design of the DC-DC converter.

Table 1. Main DC-DC converter specifications

Symbol	Parameter	Value	Unit
Operating condition			
Vin	Input DC supply voltage range	10 to 55	V
Vin_MPPT	MPPT input DC voltage range	24 to 45	V
Vout	Operating output DC voltage	350 to 430	V
Iout	Operating output current	0.8	A
Fs	Switching frequency	35	kHz
Efficiency			
Peak eff.	Peak efficiency	97.5%	-
Euro eff.	European efficiency	96.6%	-
MPPT-eff.	MPPT efficiency	99%	-

Auxiliary power supply section

The auxiliary power supply has been developed to provide stable supply voltage for different electronic components, for example, gate-drivers, microcontroller, and operational amplifiers.

In particular, the output voltages are the following:

- +15 V to supply MOSFET gate-driver, PLM module
- +5 V to supply level translator for gate driving
- +3.3 V to supply microcontroller, operational amplifiers, level translator, ZigBee module.

This auxiliary power supply is developed to supply the module also from the output, implementing anti-theft during the night. Under this condition, the PLM unit and ZigBee unit are ON also under no solar irradiance condition. This feature is guaranteed by means of a supply voltage on the DC bus provided by an external power supply.

Digital control section

The digital control section is managed by STM32, a microcontroller central unit based on ARM Cortex™-M3 32-bit RISC core operating at a 72 MHz clock frequency.

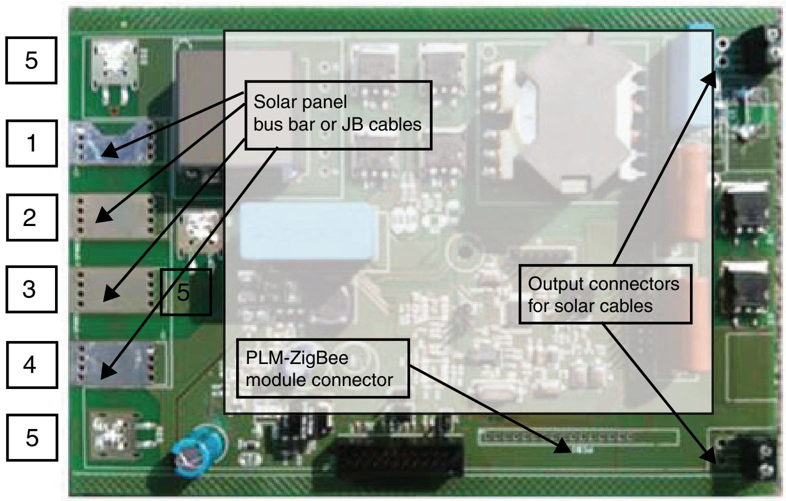
- The key features are:
  – 1.25 DMIPS/MHz (Dhrystone 2.1) performance at 0 wait state memory access
  – Single-cycle multiplication and hardware division
  – 128 Kbytes of Flash memory, 20 Kbytes of SRAM
  – 12-bit, 1 µs A/D converter
  – DMA controller
  – 16-bit timers with IC/OC/PWM
  – SysTick timer 24-bit downcounter
  – USART communication interface.

The STM32Fx controls the operation of the DC-DC converter with MPPT algorithm, monitors the input/output section with OVP and OCP, manages the synchronization with a cascaded inverter and the interface with external communication module (PLM-ZigBee).

I/O connectors

The STEVAL-ISV013V1 module is developed to be connected with photovoltaic panels (input side) and with inverters (output side). The areas 1 and 4, in *Figure 3*, are used to connect the demonstration board with a standard solar panel (with proper junction box). The areas 1-2-3-4 are used with a solar panel connected directly to this board. In this configuration, area 5 is for bypass diodes or SPV1001 cool bypass switch, an integrated smart diode by STMicroelectronics.

Figure 3. STEVAL-ISV013V1 - I/O connectors



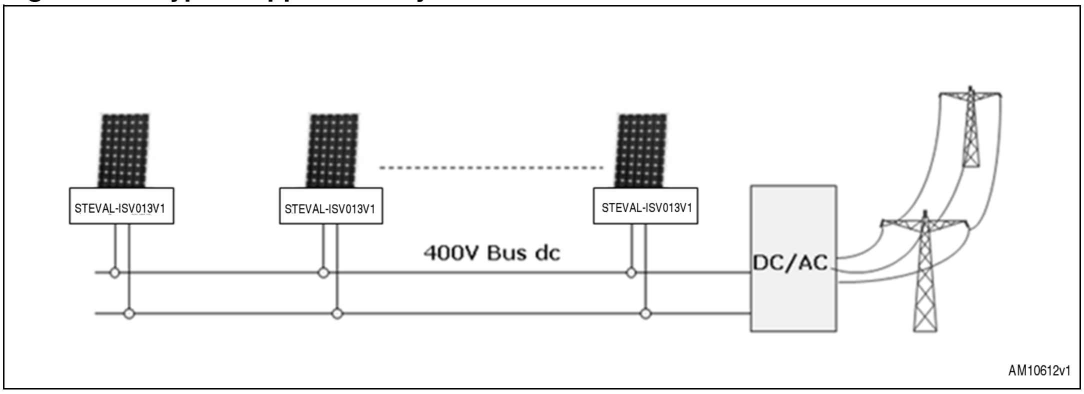
PLM - ZigBee external module connector

The STEVAL-ISV013V1 is ready to be connected to a PLM or ZigBee external module for communication. *Figure 3* shows the communication board module connector. The power supply for this module is provided by the main board.

2 Application circuit

Figure 4 shows the typical photovoltaic system architecture which can be realized with the STEVAL-ISV013V1. It is worth noting that the distributed architecture is based on parallel connection of smart panels in a high voltage DC bus. Thanks to this approach, the DC-DC stage of the standard string inverter can be removed, reducing overall system complexity and cost.

Figure 4. Typical application system



3 Electrical schematics

The power board schematic is shown in *Figure 5*. The input voltage, given by the PV panel in the range between 10 V and 55 V, is fed into the power circuit through the connector J1. The need for boosting the low input voltage to the much higher DC link voltage, required for interfacing with the inverter, is guaranteed by an isolated full bridge boost converter. The input boost inductor (L1), placed at the input side, permits low ripple current values, the output rectifying diodes (D1, D3) are placed across output capacitors, ensuring minimum voltage stress and effective voltage clamping. A high frequency transformer (TR1) is used to step up the input voltage and for functional isolation.

The auxiliary power supply, based on an isolated Flyback converter, provides the supply voltage for the microcontroller, operational amplifiers, gate-drivers and level translator. The flyback transformer (TR2) has two secondary regulated outputs for +5 V and +15 V.

An integrated voltage regulator (IC4) supplies the 3.3 V from 5 V. *Figure 6* shows the section for I/O sensing, in particular the panel output voltage and current are measured for maximum power point tracking algorithm.

The output bus voltage is controlled for overvoltage protection (OVP) and to establish the communication with the cascaded inverter.

Figure 5. Electrical schematic - power board and aux. power supply

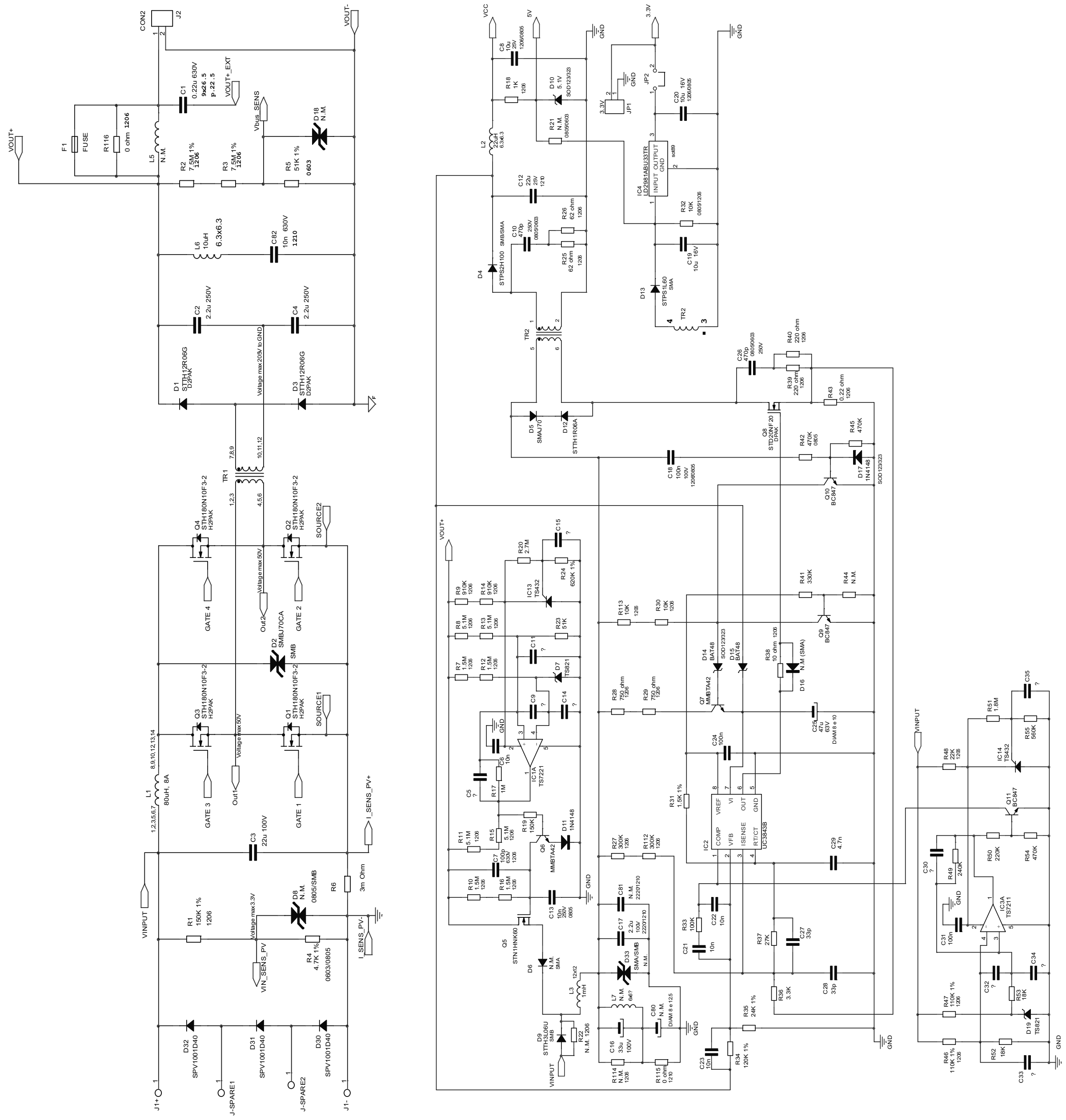


Figure 6. Electrical schematic - sensing circuit and gate driver section

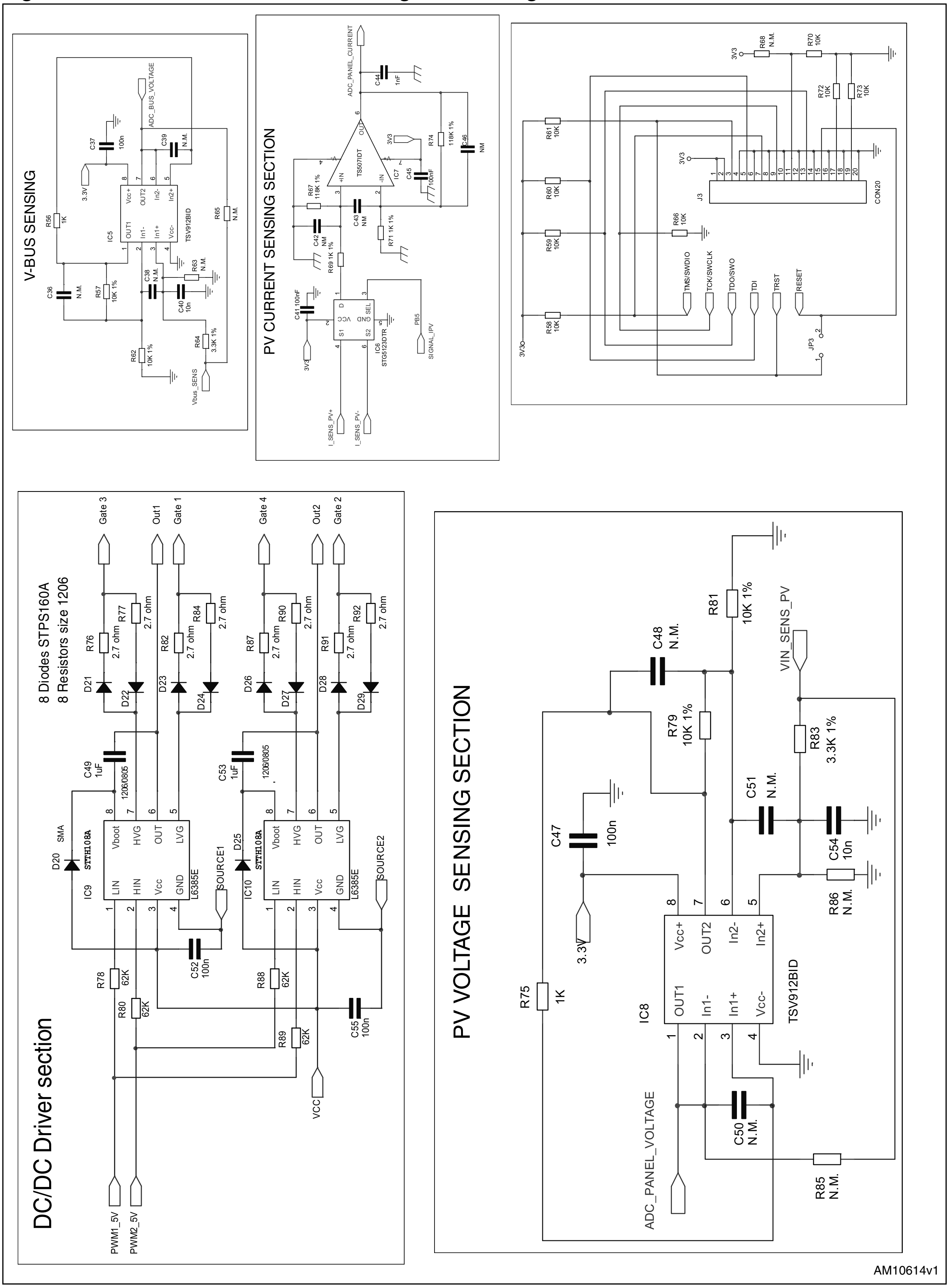
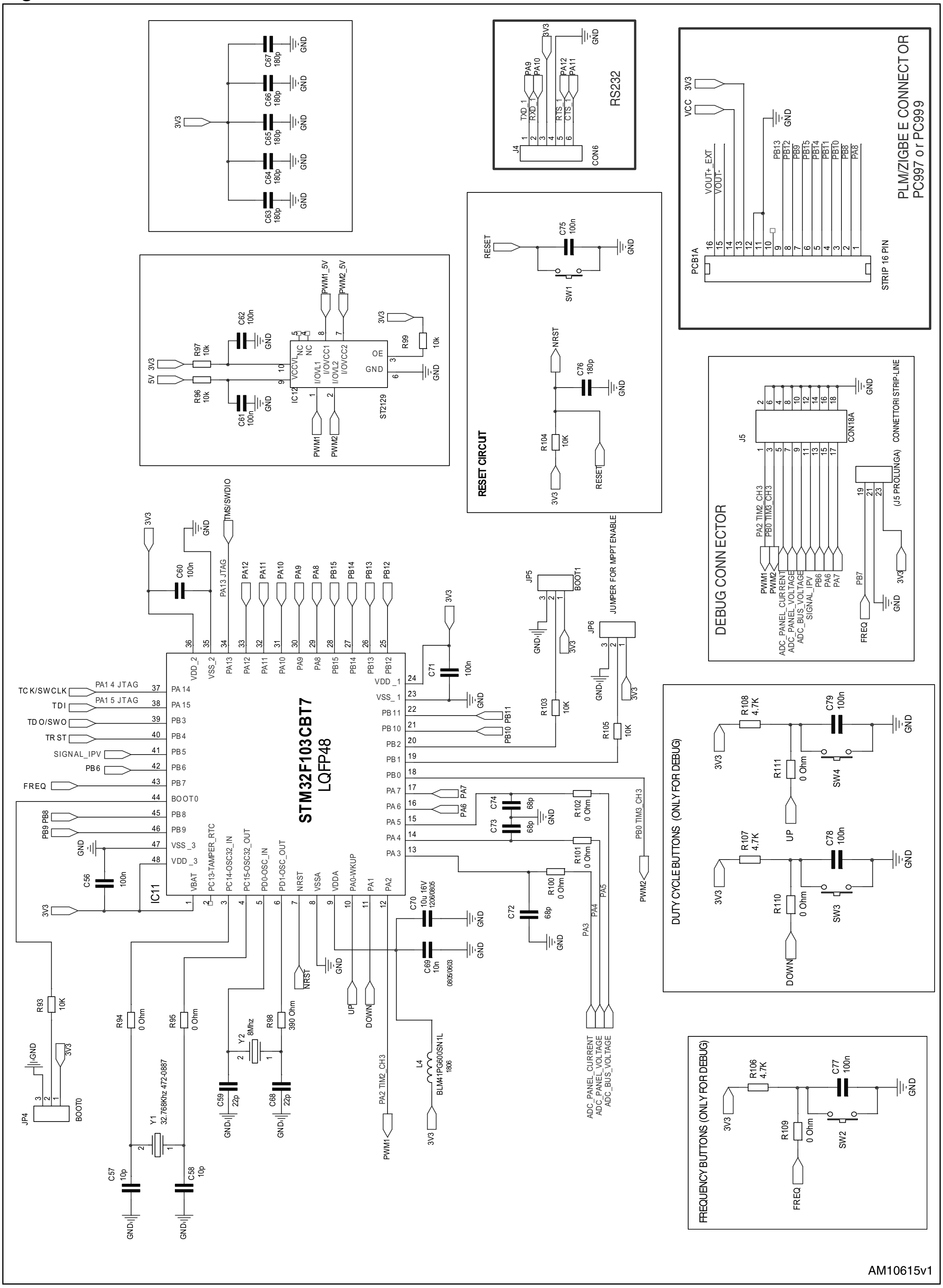


Figure 7. Electrical schematic - microcontroller and level translator

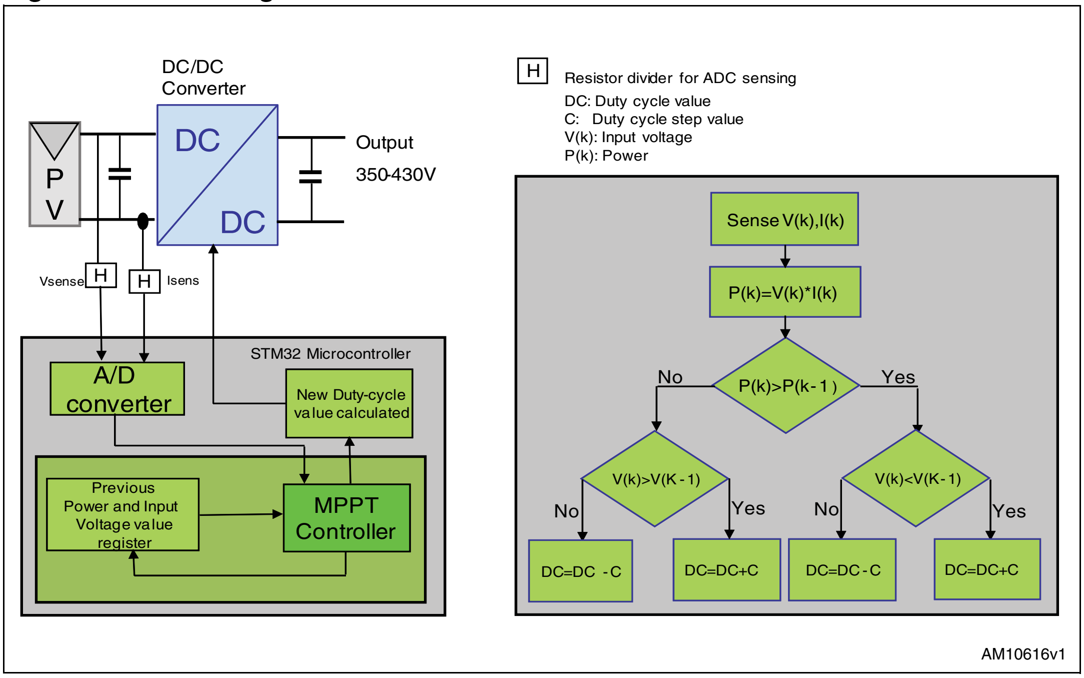


4 Digital control description

The overall control architecture requires three feedback signals for correct operation, input panel current and input panel voltage are used for maximum power point tracking; the output bus voltage is used for monitoring OV condition and to control the starting/stopping procedure.

These signals are sent to the ADC inputs of the microcontroller, according to the pin assignment of *Figure 7*, and in function of these values, two timers generate PWM output to drive the full bridge power MOSFETs or disable the driving signals to turn off the module, isolating the solar panel from the output bus. The duty cycle value is regulated by a maximum power point tracking algorithm implemented by the STM32 microcontroller (*Figure 8*).

Figure 8. MPPT algorithm embedded on 32-bit microcontroller STM32



5 Overcurrent and overvoltage protections

The overcurrent and overvoltage protections have been implemented in order to avoid damaging the hardware. The short-circuit and the open circuit condition at the output connectors (Vout+, Vout-) of the junction box forces the microcontroller to isolate the solar panel from the output. At the changed condition, the system restarts following the start-up procedure. The output voltage is limited via firmware at 430 V.

6 Revision history

Table 2. Document revision history

Date	Revision	Changes
27-Jul-2012	1	Initial release.